SPECIFICATION AMENDMENTS

The specification has added paragraph numbers, where the PCT application did not have paragraph numbers.

Please replace the numbered paragraphs in this application with the amended paragraphs of the same number below. Support for the amendment to paragraph [0039] is found at least in the specification as filed, in paragraph [0010], lines 6-7. Support for the amendment to paragraph [0042] is found at least in the specification as filed, paragraph [0008], lines 12-16.

[0007] ~~It is an object of the invention to provide~~ What is needed is a robust and reliable underwater light unit utilising modern high power LEDs in a novel enclosure which, instead of isolating the light source from the surrounding water, takes maximum benefit from the cooling potential of the surrounding water and brings the LEDs and the surrounding water into close heat-exchange relationship.

[0008] ~~The invention~~ One embodiment provides an underwater lighting unit ~~as specified in claim 1~~. The housing may be cast, formed or machined from a single piece of high thermal conductivity material such as metal, preferably stainless steel, aluminium or an aluminium alloy, or from an injection-moulded thermally conductive plastic material, so that the back and side walls are contiguous and joint-free. The plastic material may be an ABS based resin, optionally one that is glass fibre- or metal-filled; or a glass fibre-filled nylon which optionally has other thermally conductive filler present; or a polyphthalamide (PPA) resin such as that sold under the Trade Mark AMODEL. If fillers are present, then the thermal conductivity of the resin can be considerably enhanced, but preferably the fillers should be such that they do not degrade when in contact with water, especially sea-water. The thermal conductivity of an injection-moulded housing can be enhanced by incorporating into the mould a plate of thermally conductive metal such as an aluminium or aluminium-bronze which helps to conduct the heat from the LEDs to the outside edge of the housing for heat exchange with the water in which the lighting unit is immersed. If desired the outside

edge of such a metal plate can be exposed to the outside of the housing. Alternatively it may be completely encapsulated in the plastic of the housing, in which case the heat transfer to the outside surface of the housing can be enhanced by creating the encapsulating layer of the plastic housing material thin in the areas where the maximum heat transfer is to take place, for example where the encapsulated metal plate approaches the edge of the housing.

[0012] The underwater lighting unit ~~of the invention~~ is preferably assembled by arranging the LEDs in the desired array on a printed circuit board or boards against the back wall of the housing and passing the electrical leads for supplying electrical power to those LEDs through at least one aperture in the back wall of the housing. If the LEDs are arranged in a generally circular cluster then the aperture is preferably generally centrally behind the cluster. If the LEDs are arranged in a generally linear array then the aperture may be at the centre of the array or near one end of the array, or the electrical leads may pass through a pair of apertures in the back wall of the housing, situated near opposite ends of the array. The LEDs are preferably cemented in place using a heat-conductive thermosetting resin and subsequently potted in a resin which covers the whole of the back wall of the housing and encapsulates all of the printed circuit boards and soldered connections associated with the array of LEDs, leaving only the LED lenses exposed. The or each aperture in the back wall of the housing preferably leads to a hollow tubular externally screw threaded mounting stem through which the electrical leads pass, and preferably additional thermosetting resin compound is injected into that hollow tubular mounting stem so as to encapsulate the electrical leads as they pass therethrough. In that way three distinct water barriers are created between the front of the lighting unit and the rear of the mounting stem. A first water barrier is created around the edge of the glass screen which is bonded to the housing through the waterproof silicone seal. A second water barrier is created by the potting compound that encapsulates all but the lens portions of the array of LEDs. A third water barrier is created by the potting compound or by an injected silicone sealant which encapsulates the electrical connector wires as they pass through the mounting stem. An additional water barrier could, if desired, be created by incorporating a waterproof gland around the connecting wires and between the connecting wires and the mounting stem, as the wires pass from the rear of that mounting stem.

[0014] One very important application for an underwater lighting unit ~~according to the invention~~ is in underwater hull lighting systems for the hulls of yachts, boats and other marine craft. The lighting unit may be recessed into the hull of the marine craft or surface-mounted. For a recessed mounting, a lighting unit exactly as described above may be mounted across the back of a cofferdam that is recessed into the hull of the craft. No glass window is provided across the cofferdam in front of the lighting unit, so that the water in which the craft is afloat enters the cofferdam and surrounds the side wall or walls and optionally part of the back wall of the housing to achieve the LED cooling described above. The screw threaded mounting stem and associated electrical wiring pass through an optionally screw-threaded aperture in the back of the cofferdam and into the inside of the hull where it is captured by a nut together with an optional lock-nut. There is no danger at all of water passing through the lighting unit to the hull interior through the hollow mounting stem, and the only seal that is needed between the lighting unit and the rear wall of the cofferdam is a seal around the base of the mounting stem. Preferably that seal is as described and claimed in British Patent Specification No. 2258035. An annular sealing gland such as a silicone rubber seal or a polyurethane rubber seal concentric with the mounting stem is compressed between the rear wall of the housing and the back wall of the cofferdam. An outstanding annular rib is formed on the rear face of the back wall of the housing; and a cooperating annular rib is formed on the inside of the back of the cofferdam, concentrically around the mounting hole. The ribs are of different radii, so that the sealing gland is deformed as it passes around first of all the rib on the back of the lighting unit and then the rib on the back wall of the cofferdam. Such a seal is more or less as disclosed in British Patent Specification No. 2258035 but a considerable improvement in the sealing function can be obtained by having two or more annular ribs on the back of the cofferdam and two or more annular ribs on the back of the lighting unit, of progressively increasing diameters so that on tightening the sealing gland is bent into a generally corrugated shape as it is bent over the successive ribs on the lighting unit and cofferdam. If desired further sealing flanges can be provided within the hole, where the screw threaded mounting stem is secured and locked in place by a nut.

[0016] Figure 1 is an axial section through a marine hull underwater lighting unit ~~according to the invention~~ mounted in a cofferdam welded to the hull of a marine craft;

[0022] Figure 8 is a perspective view of a surface-mounting lighting unit ~~according to the invention~~ for mounting on a hull of a marine craft;

[0025] Figure 11 is a front view of a surface-mounted lighting unit ~~according to the invention~~ with external wiring; and

[0027] Referring first to the embodiment of Figures 1 to 4, the marine hull underwater lighting assembly comprises a lighting unit 1 ~~according to the invention~~ mounted at the back of a cofferdam 2 incorporated into the hull 3 of the craft. The cofferdam itself is illustrated in Figure 2, and is a flat-ended cylindrical cup, which is formed from a single piece of metal, preferably stainless steel, aluminium or an aluminium alloy, so that it is joint-free. As initially formed, the cofferdam 2 has a constant axial length as shown in Figure 2. It is then cut along the broken line 4 indicated in Figure 2, which corresponds to the hull angle at the point of installation. The angle of the line of truncation 4 can be any angle consistent with the shape of the hull at the point of installation. Angles of 50° to the vertical are easily attainable, given a sufficient axial depth of the original cofferdam 2. The cofferdam 2 is welded to the boat hull 3, both externally and internally, so that structurally it becomes an integral part of the boat hull. The only point of potential ingress of water to the inside of the hull is a central mounting aperture 5 (Figure 2) but this is reliably sealed as described below.

[0029] The lighting unit 1 ~~of the invention~~ <u>embodiment</u> comprises a housing 10 which is injection-moulded in a single piece from a highly thermally conductive plastic material or which is machined from a single piece of stainless steel, aluminium or aluminium alloy. There are therefore no joints in the housing to form potential water leakage points. The housing 10 is of dished shape, with a back wall 11 surrounded by a cylindrical side wall 12. The side wall 12 is described as a single side wall because it is circular, but a rectangular shape of lighting unit as shown in Figure 7 could be considered as having four side walls 12a, 12b, 12c and 12d. The housing of the lighting unit of Figure 7 would still, however, preferably be formed from a single injection-moulding of highly thermally conductive plastic material or from a single piece of metal, by milling.

[0034] The cofferdams 2 are generally submerged by no more than 1 or 2 metres, so the water pressure on the hull around the lighting units 1 is not excessive. However the security provided ~~by the invention~~ against leakage, and against water penetration to the interior of the hull, is massive. Water cannot pass to the hull interior through the lighting unit because the peripheral seal around the edge of the glass screen 22 provides a first seal. The glass is secure because it is a thick screen of toughened glass and because it receives support not only around its complete periphery but also across the whole of its face area from the collimators 20. A second water seal is provided by the resin 17 in which the printed circuit board or boards 14 of the LEDs 13 are set and encapsulated. A third water barrier and seal is provided by the resin or silicone sealant 18 that has been injected into the central bore of the mounting stem 16 around the wiring 15. A fourth water barrier (optional) is provided by the cap and gland 19.

[0037] It had been found that a lighting unit ~~according to the invention~~ with 30 one-watt LEDs arranged as shown in Figure 3 and an external diameter of no more than 150 mm has a light output in excess of any small sized submersible lighting unit currently on the market. However prototypes have also been constructed and tested with more than 30 three-watt LEDs in a similar configuration, and that vastly exceeds the light output of any currently available underwater lighting units of similar size and price.

[0038] The cooling water does not have to contact the back wall 11 of the lighting unit housing 10; it is sufficient that it is in good heat exchange contact with the side wall(s). The metal or highly thermally conductive plastic of the back wall 11 forms a good heat conduction path to transport the heat of the LEDs to the side walls for dissipation into the water. However ~~it is within the scope of the invention to~~ , <u>embodiments may</u> provide an oil cooling structure within the lighting unit 1 so that heat generated by the LEDs is transported by the cooling oil to the side wall(s) 12 from where it is dissipated by heat exchange with the water.

[0039] Figures 5, 6 and 7 show alternative arrays of LEDs that can be incorporated into lighting units ~~according to the invention~~. <u>Fig. 5 depicts an array of 19 LEDs 20 with</u>

circular transmission faces, while Fig. 6 depicts an array of 7 LEDs 60 with hexagonal transmission faces.

[0040] Figures 8 and 9 illustrate a surface-mounting lighting unit ~~according to the invention~~ embodiment for mounting on a hull of a yacht, boat or other marine craft below the waterline. Parts which are directly equivalent to the corresponding parts of the lighting units of Figures 1 to 7 have been given the same reference numerals as in those earlier Figures.

[0042] The housing 10 extends outwardly in a smooth curve from the rear face 11 as shown in Figure 9, and at its leading and trailing ends tapers gently towards the flat rear face 11 presenting a streamlined profile with low water resistance as in use it projects from the underwater surface of the boat hull. Heat sink 35 extends from printed circuit board 14 to the outer edge of the housing to conduct heat away from the LEDs. The heat sink may be made from any thermally conductive metal.

[0048] Figures 11 and 12 show another ~~variant of the invention~~ embodiment, being a surface-mounted lighting unit for mounting on a transom of a boat. This embodiment differs from that of Figures 8 and 9 principally in the manner of fixing the lighting unit to the boat and in the manner of supplying electrical power to the LEDs, although in addition the LEDs of the lighting unit of Figures 11 and 12 are shown in a cluster in a round housing 10 rather than in a row in an elongate housing 10 as in Figure 8.